5. Pollutant Loads: Observed and Modeled

Overall water quality in Cypress Creek is meeting water quality standards set by TCEQ, but the creek shows signs of degradation. Data reveal both spatial and temporal trends that may be due to climate variability, nonpoint source pollution, inflows from groundwater, or changes in land use and/or management in the watershed. To help understand the physical context and factors that may be influencing water quality in the creek, load duration curves were constructed using monitoring data for the primary pollutants of concern in the area: nitrogen, phosphorus, suspended sediments, *E. coli* and dissolved oxygen. These load duration curves were used to identify daily mean loading for the above parameters at monitoring sites.

Nitrogen exceedances above 0.5 mg/L tend to happen at higher flows, and these often occur in the fall and summer months. The highest exceedances are often seen when a period of very low flow is followed by a high flow event. In particular, the very dry period 2005-2006 was followed by exceedances in nitrogen targets at all sites from January through April 2007 (Figure 16). This evidence supports a nonpoint source of nitrogen in the contributing area, such as fertilizer or animal waste that builds up on the surface during dry periods and is washed in when rainfall produces surface runoff. This pattern is in contrast to the pattern of phosphorus loads, which points instead to a loading mechanism that acts at moderate flow levels.

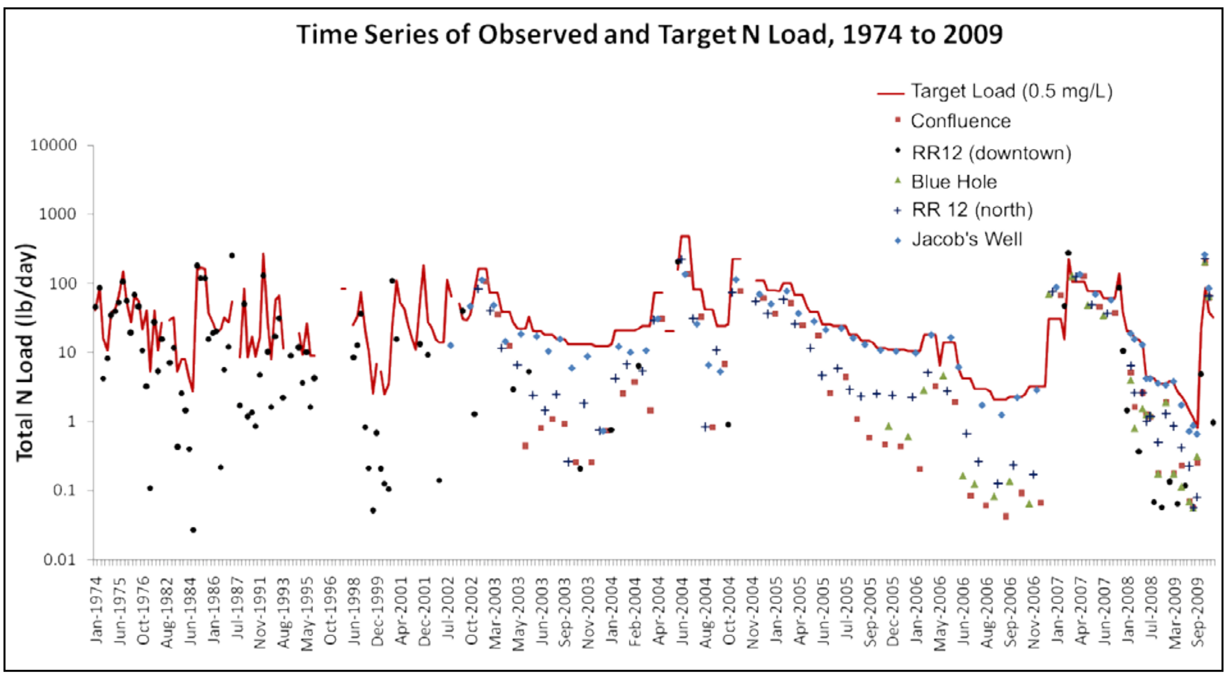


Figure 16. Time Series of Nitrogen Loads in Cypress Creek

Samples are taken monthly (CRP sites) or quarterly (TCEQ site). The red line indicates target loads calculated based on available flow estimates and 0.5 mg/L concentration. Points above this line represent exceedances of the target load.

A time series of target maximum (5.0 mg/L) and observed sediment concentrations reveals that there are a cluster of TSS exceedances that occurred from spring 2005 through fall 2006 (Figure 17). A major roadway, Winters Mill Parkway, was under construction from October 2005 to July 2007 in the southeastern portion of the watershed. Some of the highest relative exceedances in the spring of 2006 may be associated with the construction of this road, although RR12 downtown and the confluence both had exceedances in the spring of 2005 before work started. Instream dredging operations were documented in 2005. In addition exceedances occur at all sites during this period, including those above the influence of bypass construction. Other construction activities along RR12 and Jacob's Well Rd. could contribute excess sediment to the creek as well, if proper stormflow mitigation measures are not employed.

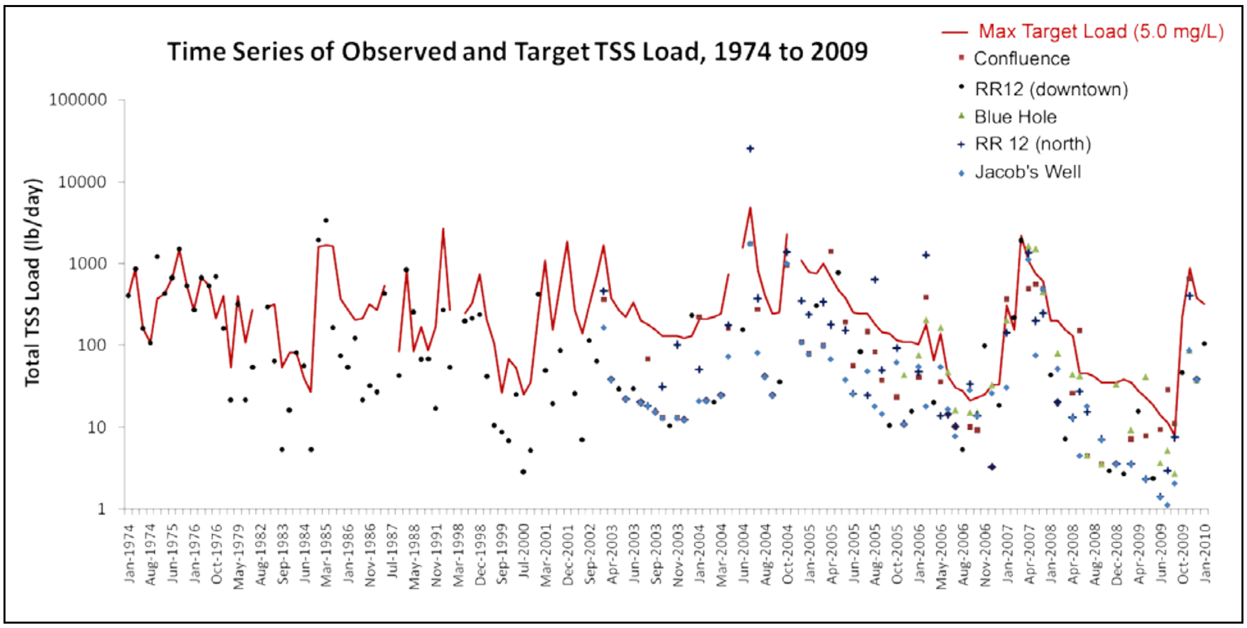


Figure 17. Time Series Of Observed And Target Maximum Sediment Loads In Cypress Creek

Samples are taken monthly (CRP sites) or quarterly (TCEQ site). The red line indicates target loads calculated based on available flow estimates and 5.0 mg/L concentration. Points above this line represent exceedances of the target load.

Figure 23 and Figure 24 below show *E. coli* measurements at five sites in Cypress Creek. Higher *E. coli* values are correlated with elevated TSS levels at all sites (except at Jacob's Well, which tends to generally have the lowest bacteria concentrations due to the influence of spring flow.

For DO, a parameter of concern due to the 303(d) listing in the year 2000, trends show that maintaining a minimum flow is critical. 10th, 20th, 30th, etc. percentiles were calculated for flows estimated at the confluence between 2000 to 2009, and DO observations plotted at each level (Figure 26, Figure 27). For all sites, a flow level between 1.31 and 4.1 cfs appears to be sufficient to sustain DO levels above 4.0 mg/L at least 75% of the time. Between 4.11 and 5.1 cfs, DO is above 6.0 mg/L at least 75% of the time, which is the target level.

To get watershed wide pollution concentrations the SWAT model was used to simulate instream pollution concentrations for all reaches of Cypress Creek. The sources of NPS pollution were determined by using Event Mean Concentrations or EMCs (Baird, Jennings, Ockerman, and Dybala 1996). To do this, the Soil and Water Assessment Tool (SWAT) was used to simulate an average annual water yield for each subwatershed. These modeled water yields were necessary for the EMC equations used to calculate pollutant loads and identify potential sources of NPS pollution for existing and future conditions. The Texas Administrative Code describes the designated uses and water quality criteria required to meet those designations (Table 10). Because there are no criteria for nitrogen, the Stakeholder Committee determined a target level (Table 12) for nitrogen that is more conservative than state screening levels. The modeled instream pollutant concentrations are used to identify reaches of Cypress Creek that need targeted attention to mitigate water quality.

Table 10. Cypress Creek Designated Uses and Criteria

Cypress Creek Site Specific Uses and Criteria (Classified Segment)						
Seg #	**Segment Name**	**Recreation**	**Aquatic Life**	**Domestic Water Supply & Aquifer Protection**		
1815	Cypress Creek	PCR	E	PS/Aquifer regulated activities: any construction/post-construction activity occurring on the contributing zone of the Edwards Aquifer that has the potential for contributing pollution to surface streams that enter the Edwards Aquifer recharge zone (§213.21)		
Criteria						
Cl^{-1} (mg/L)	**SO_4^{-2}** (mg/L)	**TDS** (mg/L)	**DO** (mg/L)	**pH Range** (SU)	***E. coli*** #/100ml	**Temperature** (°F)
50	50	400	6.0	6.3-9.0	126	86
* The aquifer protection use applies to the contributing, recharge and transition zones of the Edwards Aquifer.						

Methods of Analysis

The Meadows Center and Stakeholder Committee utilized the Soil and Water Assessment Tool (SWAT 2000) and Event Mean Concentration calculations to enhance their knowledge about pollution in the watershed, identify sources of pollution, and assist with determining strategies and best management practices.

Watershed delineation was performed using the Automated Geospatial Watershed Assessment (AGWA) tool, an interface for ESRI's ArcGIS jointly developed by the U.S.

Environmental Protection Agency, U.S. Department of Agriculture (USDA) Agricultural Research Service, and the University of Arizona to automate the parameterization and execution of two commonly-used hydrologic models (Miller et al., 2007). The AGWA delineation and discretization process utilizes the hydrology utilities provided by ArcGIS to define watersheds and stream networks. Watershed delineation segments a region into several hydrologically connected subwatersheds for use in characterization and modeling. AGWA's delineation tool requires an elevation raster, which was obtained from the USGS's National Map Seamless Server (USGS, 2010). This data set has a resolution of approximately 10 meters and is processed to filter artifacts and fill missing data at quadrangle seams. Automatic delineation uses a threshold method of contributing source areas (CSA) to delineate hydrologically distinct areas. The threshold parameter may be increased to decrease the number of sub-basins, or conversely, decreased to increase the number of sub-basins. CSA was varied from 1.0% (243 acres) to 2.5% (608 acres). In addition, stormflow gauge locations were used to create breaks between watersheds so that model output at those locations can be directly compared to measured values. The resulting delineations were compared to roads and other infrastructure to choose the best balance between the number and resolution of basins and potential watershed management units. The final delineation yielded 46 subwatersheds within the watershed of Cypress Creek (Figure 15) above. This subwatershed delineation was used to calculate statistics for soils, land uses, and pollutant loadings.

Watershed modeling of the Cypress Creek contributing area was performed using the Cypress Creek Decision Support System (CCP-DSS), a modeling and results visualization package based on the Automated Geospatial Watershed Assessment (AGWA2) tool. AGWA2 is an interface for ESRI's ArcGIS jointly developed by the U.S. Environmental Protection Agency, U.S. Department of Agriculture (USDA) Agricultural Research Service, and the University of Arizona to automate the parameterization and execution of two commonly-used hydrologic models, SWAT and KINEROS (Miller et al., 2007). The CCP-DSS is based on the AGWA2 system and in addition has been populated with all the relevant local data to perform scenario analyses on the Cypress Creek watershed.

The Soil and Water Assessment Tool (SWAT) was used to model flow, sediment, and nutrients across the watershed and stream channels. This model uses information on soils, topography, land cover, rainfall, and temperature to simulate hydrologic processes on the land surface that create surface flow, infiltration and subsurface flow, and routes these flows, sediment and nutrients through stream channels. It is a continuous simulation model, so outputs can be daily, monthly, or annual means for a period of several years to decades. Daily data from 2000 to 2009 were used to run the model and to compare the simulated outputs to observations. Daily flows and nutrient loadings simulated in each subwatershed from 2000-2009 were averaged and selected results are presented below. Existing BMPs were not surveyed for this study; therefore the model results presented represent initial estimates of average runoff and pollutant loadings based on known land uses and the physical properties of the area. Additional calibration of the model to incorporate existing BMPs and new monitoring data is recommended. Please refer to the Technical Reference Document for more details on model development, inputs, and calibration.

Water yield is defined as the average amount of water leaving a subwatershed or channel. Model results show an average water yield across the watershed of 8.5 in, meaning that for an average annual rainfall of 35 in, about 8.5 in of that will flow out of the upland areas to the main stream channel. Model results indicate that a great deal of flow losses occur in the upper portions of the watershed through rapid infiltration and channel loss. Some of these flows travel through the shallow subsurface and reappear in downstream channels, while others are lost to deep percolation and/or used by vegetation. Areas that yield the largest amounts of water also have the greatest potential to carry high volumes of pollutants in this water, so these areas should be targeted for BMP implementation to mitigate both nonpoint source pollution and flood risk (See Figure 9). Simulated average water yields for each subwatershed were also used along with data on land uses to calculate pollutant loadings for some additional parameters of interest as discussed in 5.0 Nonpoint Source Pollution Section of the WCR found in the Technical Reference Document.

Land Use Analysis

Methods

Land use characterization for the Cypress Creek watershed was determined using Hays Central Appraisal District (HaysCAD) 2009 cadastral data. At the time that the work on characterizing the watershed began, this data was received as an incomplete GIS parcel layer from HaysCAD, with parcel polygons outlined and a separate, partially completed annotation file containing tax reference numbers (R numbers). Thus, identification of parcel by R number was available for approximately 82% of the watershed. Spatial parcel data was joined (by R number) to a Wimberley Independent School District (WISD) 2009 tax roster, allowing each parcel to have data populated regarding relevant owner name, address, property values and existing land use/land type codes.

HaysCAD state code values were reclassified into a land use system of eight classes: Residential (A, B), Large Lot Residential (ALg), Undeveloped/Open-space (C), Agriculture (E), Commercial (F), Industrial (J), Parks (P) and Transportation (T). Since the protocol at HaysCAD is to identify properties by their zoned/potential land use type, many of the parcels that were coded as a residential type of land use were in fact still vacant lots, i.e. platted but undeveloped. The goals of the characterization involved evaluating current land use practices, so ground-truthing was conducted using 2008 aerial imagery from Capital Area Council of Governments (CAPCOG). Any parcel that was coded as residential but had no structure built on the property was re-coded as undeveloped. Also, any other necessary updates were made, such as coding all roads as transportation and creating and coding the parks classification. This 55 allows for an accurate assessment of where and what type of development has occurred in the watershed to date. There are a few known conservation easements and wildlife management areas within the watershed, but the exact nature and impacts on land management are not known. Therefore, in those areas the initial land use classification was used, which for these parcels was predominantly Rangeland.

Pollution Loading by Source

Estimating annual pollutant loadings can be very useful for identifying the types of nonpoint source pollution from different parts of the watershed and understanding the magnitude of loadings that need to be managed with the Watershed Protection Plan. Although the Cypress Creek watershed has a good record of ambient water quality in the watershed, these values have not been separated into the contributions from component land uses. In addition some parameters, such as oil/grease and biochemical oxygen demand (BOD), are not included in the current data set. EMCs for various agricultural and urban NPS pollution constituents are given in Baird et al., 1996. These values have been used in several studies in Texas when localized EMCs are not available. In order to augment the results from the SWAT model and to characterize the relative loading contribution from different land uses, annual loadings for various pollutants were estimated using a modeled mean annual water yield along with EMCs given in the Baird et al. (1996) land use study (see Table 11) using the formula outlined in the EMC Method section below.

Table 11. EMC Estimates for Selected NPS Constituents (From Baird Et Al., 1996)

Constituent	Land Use						
	Residential	Commercial	Industrial	Transportation	Cropland	Rangeland	Undev/Open
Total Nitrogen (mg/L)	1.82	1.34	1.26	1.86	4.40	0.70	1.50
Total Kjeldahl Nitrogen (mg/L)	1.50	1.10	0.99	1.50	1.7	0.20	0.96
Nitrate + Nitrite (mg/L as N)	0.23	0.26	0.30	0.56	1.6	0.40	0.54
Total Phosphorus(mg/L)	0.57	0.32	0.28	0.22	1.3	<0.01	0.12
Dissolved Phosphorus(mg/L)	0.48	0.11	0.22	0.10	--	--	0.03
Suspended Solids(mg/L)	41.0	55.5	60.5	73.5	107	1.0	70
Dissolved Solids(mg/L)	134	185	116	194	1225	245.0	--
Total Lead (µg/L)	9.0	13.0	15.0	11.0	1.5	5.0	1.52
Total Copper (µg/L)	15.0	14.5	15.0	11.0	1.5	<10	--
Total Zinc (µg/L)	80	180	245	60	16	6.0	--
Total Cadmium (µg/L)	0.75	0.96	2.0	< 1	1.0	<1.0	--
Total Chromium (µg/L)	2.1	10.0	7.0	3.0	<10.0	7.5	--
Total Nickel (µg/L)	< 10	11.8	8.3	4.0	--	--	--
BOD (mg/L)	25.5	23.0	14.0	6.4	4.0	0.5	--
COD (mg/L)	49.5	116	45.5	59	--	--	40
Oil and Grease (mg/L)	1.7	9.0	3.0	0.4	--	--	--
Fecal Coliform(colonies/100 ml)	20,000	6,900	9,700	53,000	--	37	--
Fecal Strep.(colonies/100 ml)	56,000	18,000	6,100	26,000	--	--	--

-- Data not available

Values shown as <0.01, <1, and <10 indicate that all or most of the values were below the reporting limit.

Time period for data is 1992-1993 except for cropland and rangeland, which was collected 1970-1995.

EMC Method

Mean annual water yields for each subwatershed were converted to runoff volume ($\frac{m^3}{yr}$) by converting to meters and multiplying by the total area of the subwatershed. EMCs for land use-constituent combinations for which no estimates are provided are not included in loading estimates. Also, EMC values below detection limits (i.e. <0.01) also were not included. NPS loadings for each constituent are calculated as the sum of EMCs for each land use multiplied by runoff volume and scaled by the relative area in each land use:

$$l_x = \sum(0.001EMC_{x1} * Q * a_1) + (0.001EMC_{x2} * Q * a_2) + \cdots + (0.001EMC_{ax} * Q * a_{n*})$$

Where l_x = annual loading of constituent *x* ($\frac{kg}{yr}$)

EMC_{x1} = event mean concentration of constituent *x* from land use 1 ($\frac{mg}{L}$)

Q = water yield (runoff volume) $(\frac{m^3}{yr})$
a_1 = percent of watershed area in land use 1

The results are then converted to unit loads (per unit area) given the formula:

$$L_x = \frac{10\ 000 * l_x}{A}$$

Where L_x = annual unit loading of constituent *x* (kg/ha/yr)
A = total area of subwatershed (m^2)

Finally, loading estimates were converted to pounds per year (lb/year).

Water Quality Analysis

In order to preserve water quality and mitigate continued degradation, the Stakeholder Committee chose a water quality target for nitrogen that is stricter than state screening levels. Below is a summary of the water quality analysis (see Technical Reference Document).

It is important to note that because this project was carried out over 5 years, monitoring data is referred to as historical data (pre 2008), recent monitoring data (collected in 2008-2010) or new data (post 2010 stakeholder supplied data for BMPs).

Dissolved oxygen is of concern because the creek was briefly listed on the 303(d) list for inadequate DO levels in 2000. In addition, new data provided by GBRA in the 2013 CRP report (pg. 51) indicated a downward trend in DO in Cypress Creek. Stakeholder input was used to identify desired flow conditions required to maintain adequate DO levels. Mean bacteria concentrations in Cypress Creek are at attainment, but high concentrations have been identified at different points along the creek and are of concern as development in the watershed continues. Increased impervious cover is a concern because it contributes to higher pollutant concentrations during rain events and decreases localized groundwater recharge. Oil and grease was designated as a parameter of concern by the Stakeholder Committee. A 300-500% increase was determined to be acceptable when considering a full build-out scenario. Future modeling and increased monitoring will allow for a better understanding and improved targets during the implementation phase. Table 12 identifies the targets and standards for pollution parameters of primary concern. The Stakeholder Committee determined a goal of meeting state standards where applicable in the early years of implementation, and will strive for Stakeholder Committee established targets by the later years of the implementation process.

Table 12. Target Levels For Pollutant Constituents And Parameters Of Concern

Pollutant	State Standard or Screening Level if Applicable***	Target at a Minimum Cypress Creek Stakeholder Committee	Source of Information
Nitrogen (N)	---	Target- 1.65 mg/L	Cypress Creek Stakeholder Committee
	Nitrate screening level- 1.95 mg/L	---	TCEQ
Parameters of Concern		**Objectives**	**Source of Information**
Total Suspended Solids (TSS)	---	---	Cypress Creek Stakeholder Committee
	Screening level- 5.0 mg/L	---	TCEQ
Escherichia coli (E. coli)	Single sample- 394 cfu/100mL Geometric mean- 126 cfu/100mL	Single sample- 394 cfu/100mL Geometric mean- 126 cfu/100mL	TCEQ
Dissolved Oxygen (DO)	24-hr mean values above 6.0 mg/L Grab sample values above 4.0 mg/L	24-hr mean values above 6.0 mg/L Grab sample values above 4.0 mg/L	TCEQ
Flow	---	Jacob's Well- 3.8 to 6.4 cfs Blanco Confluence- 4.11 to 5.1 cfs Cypress Creek- 4 to 6 cfs	Cypress Creek Stakeholder Committee
Impervious Cover	---	15-20%	Cypress Creek Stakeholder Committee
Oil & Grease	---	No more than a 300-500% increase from current conditions	Cypress Creek Stakeholder Committee

* Unless otherwise noted, targets are for all CRP and TST monitoring sites, including confluence with the Blanco River.
** Targets are reported in annual averages, which allow for exceedances on individual sampling events, provided that the average of all events in a one year period do not exceed the specified target levels.
***State water quality standards have not been established for N, TSS, Flow, Impervious Cover, and Oil & Grease. N and TSS have a state screening level established.

Instream Pollution Concentration from SWAT Model

The SWAT model was used to simulate instream pollution concentrations in the creek for the Existing and Future scenarios. The results were used to identify reaches of the creek that currently and are expected to have pollution concentrations above stakeholder determined targets. The SWAT model uses observed precipitation and temperature data to simulate the amount of overland and instream flow based on elevation, slope, soil characteristics, the creek's physical characteristics and potential losses to karst features and or evaporation. To keep instream pollution concentrations in the same units and time step used in the EMC calculations, discussed in the following section, SWAT model results are shown as mean annual values with annual load reductions needed to meet stakeholder determined targets for nitrogen in the Existing and Future scenarios (Table 13 and Table 14).

Table 13. 2009/Existing Development Scenario

Mean Annual Instream Concentrations and Reductions Needed

Sub ID	Nitrogen Instream Load (Target = 1.5 mg/L)	Nitrogen Reduction Needed (mg/L)	% Nitrogen Reduction Needed*
2	1.66 mg/L	.16 mg/L	9%
4	1.63 mg/L	.13 mg/L	8%
7	1.64 mg/L	.14 mg/L	9%
32	1.86 mg/L	.36 mg/L	19%
35	1.66 mg/L	.16 mg/L	10%

* Estimated pollution load reductions needed to meet water quality goals in the watershed. This analysis is submitted to satisfy Element B of the EPA 9-element criteria for watershed-based plans.

Table 14. 2050/Future Full Development Scenario

Mean Annual Instream Concentrations and Reductions Needed.

Sub ID	Nitrogen Instream Load (Target = 1.5 mg/L)	Nitrogen Reduction Needed (mg/L)	% Nitrogen Reduction Needed
2	1.78 mg/L	0.28 mg/L	16%
4	1.68 mg/L	0.18 mg/L	11%
7	1.67 mg/L	0.17 mg/L	10%
32	1.90 mg/L	0.40 mg/L	21%
35	1.69 mg/L	0.19 mg/L	11%

* Estimated pollution load reductions needed to meet water quality goals in the watershed. This analysis is submitted to satisfy Element B of the EPA 9-element criteria for watershed-based plans.

Because there is a great deal of potential variability in runoff depths, both spatially between subwatersheds and temporally between wet and dry years, the Meadows Center used SWAT model outputs to identify instream concentrations that are above stakeholder determined target concentrations identified in Table 12. In reaches with concentrations above stakeholder determined targets EMCs were used to identify the potential sources of nitrogen for the subwatersheds that contribute flows to that reach (Figure 18, Figure 19, Figure 20, Figure 21).

Nitrogen and TSS Loads from EMC Calculations by Land Use

Likely sources of NPS pollution in the watershed include urban runoff, on-site septic treatment, residential landscaping, agricultural activities, fertilizer and pesticide application, land clearing for new construction, pet and livestock wastes, runoff from roads and parking lots, grazing activities, atmospheric deposition, and recreational use of the creek. Pollutant loadings were identified by subwatershed during the 2010 characterization of the watershed. Analysis of the EMC results for the Existing Scenario show that a majority of nitrogen comes from undeveloped land (Table 15). In the Future Scenario (Table 16), undeveloped land is still the largest contributor of nitrogen and TSS to the watershed, but increased residential land cover increases loads to approximately five times more nitrogen and TSS from this source. Existing residential land use is projected to increase by approximately 440% from 5% to 27% of the watershed (Table 7). With this change, nitrogen increases 371%, from 7% to 33%. TSS increases by 400% from 4% to 20%. Event mean concentration calculations show that the growth of residential land area is primarily responsible for total increased pollutant loadings by acre, as seen in Technical Reference Document F – Event Mean Concentration Calculation Results by Subwatershed.

The undeveloped land use is the largest source of potential loadings for nitrogen and TSS because it accounts for 80% (19,426 ac) of the total area (24,327 ac); whereas, the residential land use accounts for only 5% (1,231 ac) of the area. Although the residential nitrogen event mean concentration (EMC) is higher than the undeveloped EMC, the undeveloped contributes more due to its size. Both nitrogen and TSS potential loadings are calculated as a function of the percent of land use and EMC, therefore, the undeveloped area contributes approximately 82% of the nitrogen load and 91% of the TSS potential load mostly due to large amount of undeveloped land (19,426 ac). The event mean concentration (EMC) values are derived from EMC monitoring and research conducted in Texas by Baird et al.

Commercial land use is projected to increase by 400% in this Future Scenario, which causes a 400% increase in nitrogen and TSS. Industrial and Transportation land uses do not undergo a significant change and therefore, water quality modeling does not indicate a significant change in nitrogen and TSS loads. Rangeland decreases by 27% which results in a 40% reduction in nitrogen and 0% in TSS. Finally, undeveloped land decreases by 29% which causes a 34% reduction in nitrogen and a reduction of 24% TSS (See Table 17 and Table 18).

Table 15. Existing Scenario: Contribution from Source Land Uses

Existing Land Use Coverage in Cypress Creek Watershed	Area (acres)	Nitrogen EMC	Total Nitrogen Load	Percent of Nitrogen Load	TSS EMC	Total TSS Load	Percent of TSS Load
Residential	1231.57 acres	1.82 mg/l	2479.02 lb/yr	7%	41 mg/l	55846 lb/yr	4%
Commercial	200.01 acres	1.34 mg/l	282.55 lb/yr	1%	55.5 mg/l	11702.54 lb/yr	1%
Industrial	15 acres	1.26 mg/l	21.52 lb/yr	<1%	60.5 mg/l	1033.35 lb/yr	<1%
Transportation	798.12 acres	1.86 mg/l	1502.21 lb/yr	4%	73.5 mg/l	59361.54 lb/yr	4%
Rangeland	2656.78 acres	.70 mg/l	1809.45 lb/yr	5%	1 mg/l	2584.93 lb/yr	<1%
Undeveloped	19426.08 acres	1.50 mg/l	28241 lb/yr	82%	70 mg/l	1317912.15 lb/yr	91%
TOTAL	24327.56		34335.72			1448440.51 lb/yr	

* Estimated pollution load reductions needed to meet water quality goals in the watershed. This analysis is submitted to satisfy Element A of the EPA 9-element criteria for watershed-based plans.

Table 16. Future Scenario: Contribution from Source Land Uses

Future Land Use Coverage in Cypress Creek Watershed	Area (acres)	Nitrogen EMC	Total Nitrogen Load	Percent of Nitrogen Load	TSS EMC	Total TSS Load	Percent of TSS Load
Residential	6434.11 acres	1.82 mg/l	13053.63 lb/yr	33%	41 mg/l	294065.4 lb/yr	20%
Commercial	1235.57 acres	1.34 mg/l	1967.92 lb/yr	5%	55.5 mg/l	81507.24 lb/yr	6%
Industrial	11.56 acres	1.26 mg/l	19.42 lb/yr	<1%	60.5 mg/l	932.67 lb/yr	<1%
Transportation	798.55 acres	1.86 mg/l	1738.59 lb/yr	4%	73.5 mg/l	68702.46 lb/yr	5%
Rangeland	1932.66 acres	.70 mg/l	1335.62 lb/yr	3%	1 mg/l	1908.03 lb/yr	<1%
Undeveloped	13904.58 acres	1.50 mg/l	21383.92 lb/yr	54%	70 mg/l	997916.17 lb/yr	69%
TOTAL			39499.11 lb/yr			1445031.97 lb/yr	

* Estimated pollution load reductions needed to meet water quality goals in the watershed. This analysis is submitted to satisfy Element B of the EPA 9-element criteria for watershed-based plans.

Table 17. Land Use Contributions to Nitrogen and TSS Loads

Change of Land Use Coverage and Loads in Cypress Creek Watershed	Change in Land Use Cover	Existing Percent of Nitrogen Load	Future Percent of Nitrogen Load	Change in Nitrogen Load	Existing Percent of TSS Load	Future Percent of TSS Load	Change in TSS Load
Residential	440%	7%	33%	371%	4%	20%	400%
Commercial	400%	1%	5%	400%	1%	6%	500%
Industrial	0%	<1%	<1%	0%	<1%	<1%	0%
Transportation	0%	4%	4%	0%	4%	5%	25%
Rangeland	[-27%]	5%	3%	[-40%]	<1%	<1%	0%
Undeveloped	[-29%]	82%	54%	[-34%]	91%	69%	[-24%]

* Estimated pollution load reductions needed to meet water quality goals in the watershed. This analysis is submitted to satisfy Element B of the EPA 9-element criteria for watershed-based plans.

The Meadows Center modeled instream pollution concentrations and calculated mean annual loads by subwatershed for nitrogen and Total Suspended Solids in pounds per year (lb/yr) from modeling results and EMCs. The main sources for nitrogen are urban runoff, OSSFs and the open/undeveloped land use that includes Agricultural activities that require erosion/sediment control and pesticide management. Loadings by Subwatershed can be found in the Technical Reference Document - EMC Calculation Results by Subwatershed.

Stakeholders identified priority reaches 2, 4, 7, 32, and 35 because they have relatively high baseline nitrogen concentrations. Stakeholders identified additional priority subwatersheds 1, 24, and 28 because they have significant baseline overland nitrogen contributions. Secondary stakeholder priorities include subwatersheds 9, 27, 29, 36, 44, 45, and 46 because these have baseline nitrogen concentrations that are relatively high and may become above the target in the future.

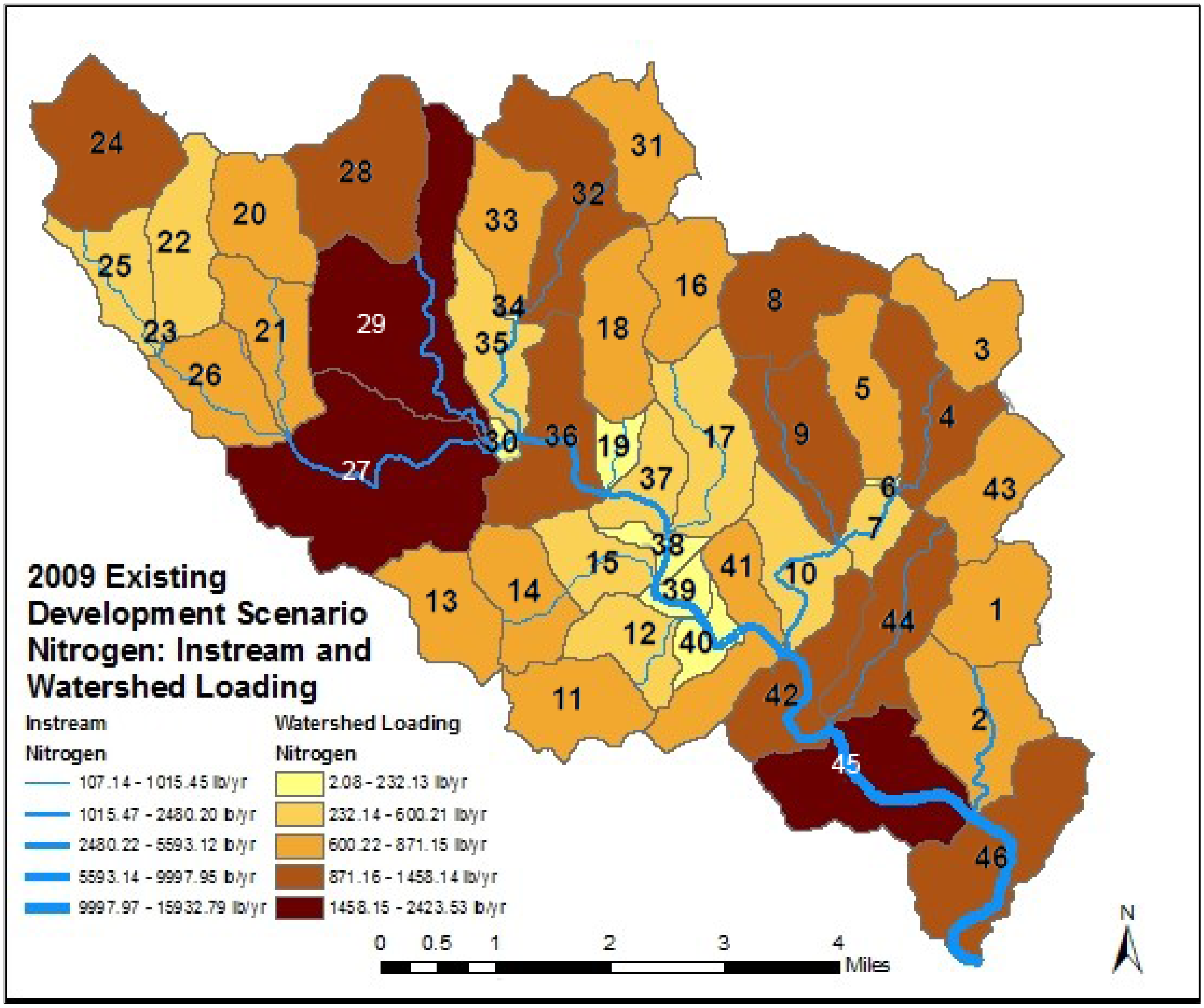


Figure 18. 2009 Existing Nitrogen Modeled Instream Loads

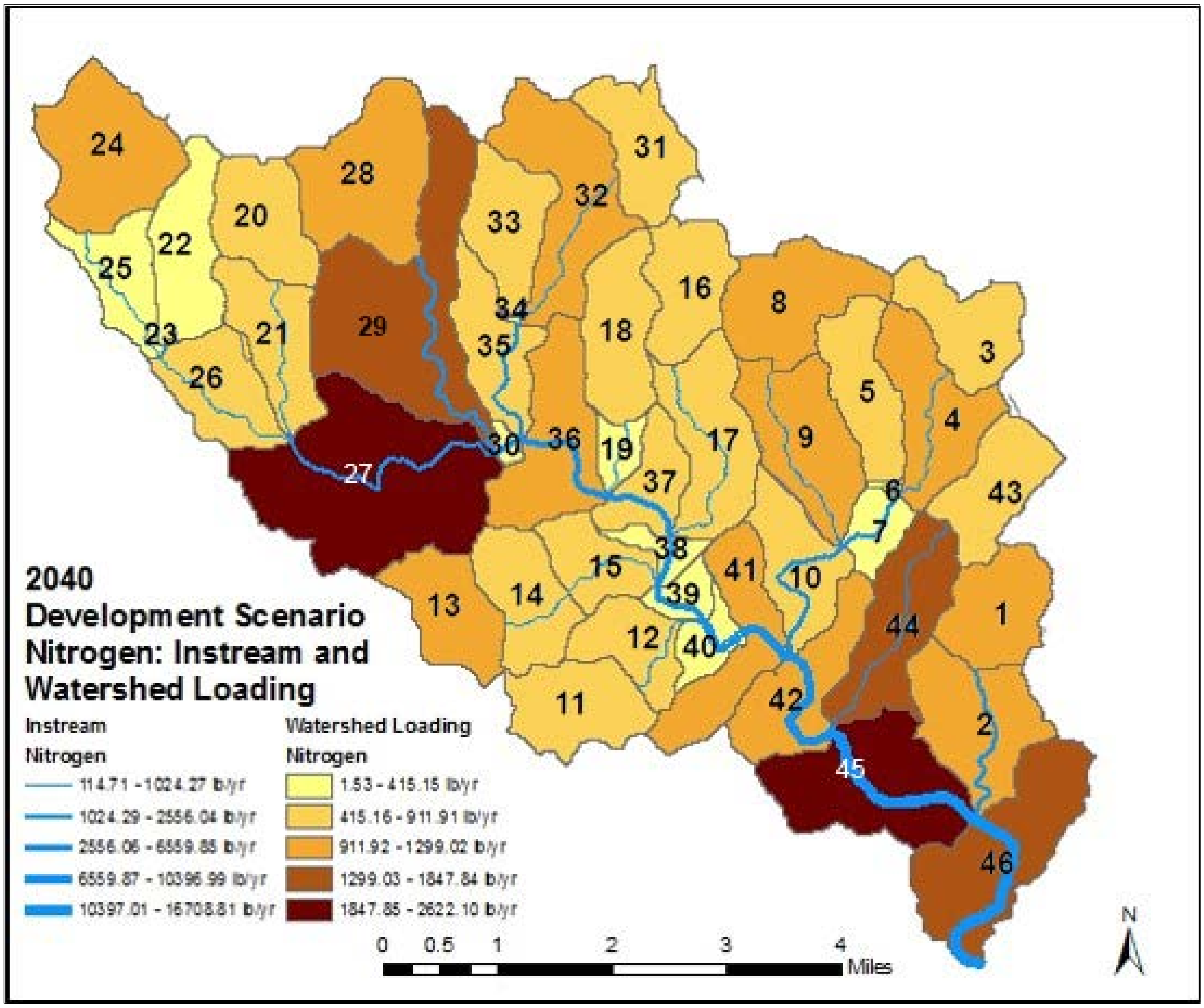


Figure 19. 2040 Future Nitrogen Modeled Instream Loads

Stakeholders identified priority reaches 2, 4, 9, 14, 27, 29, 32, 36, 41, 42, 44, 45, and 46 because they have high baseline TSS concentrations. Stakeholders identified additional priority subwatersheds 8, 24, and 28 because they have high baseline overland TSS contributions. All subwatersheds are expected to exceed targets when flows are low.

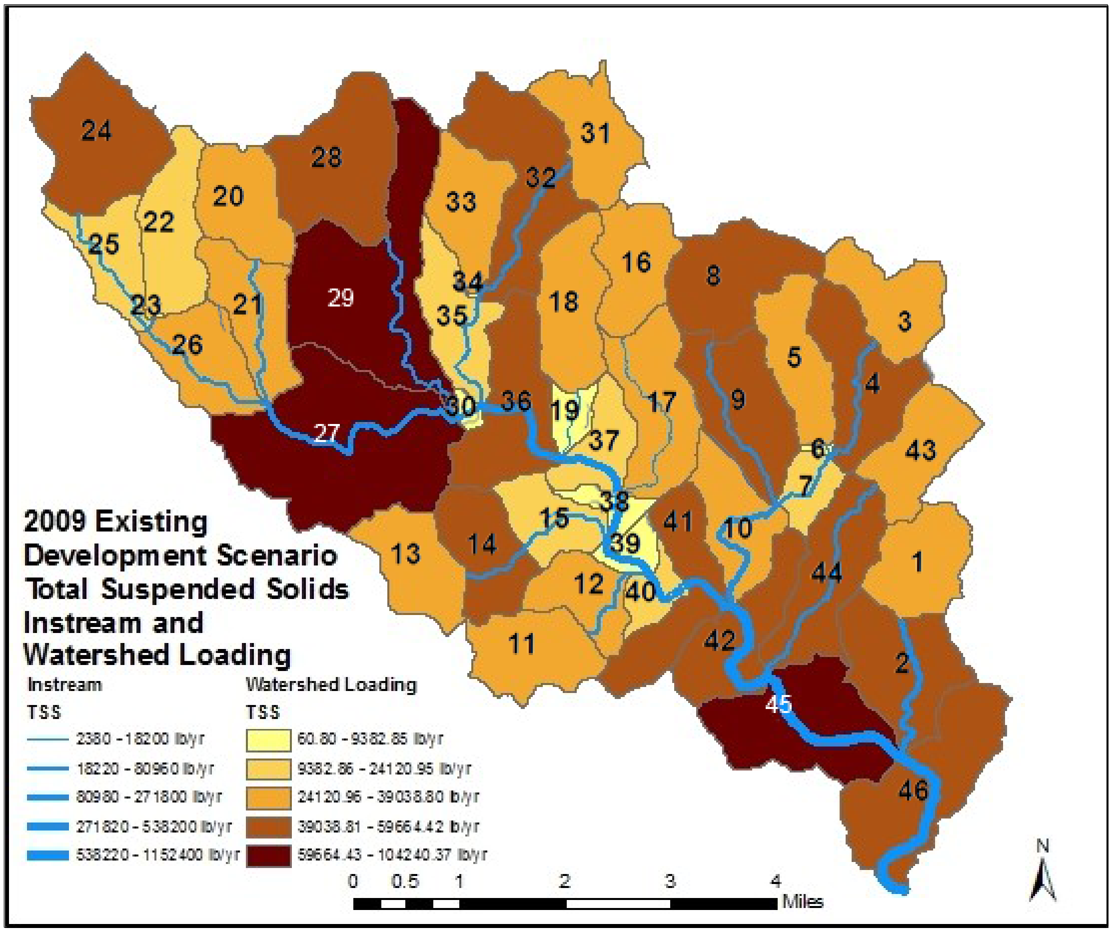


Figure 20. 2009 Existing Total Suspended Solids Modeled Instream Loads

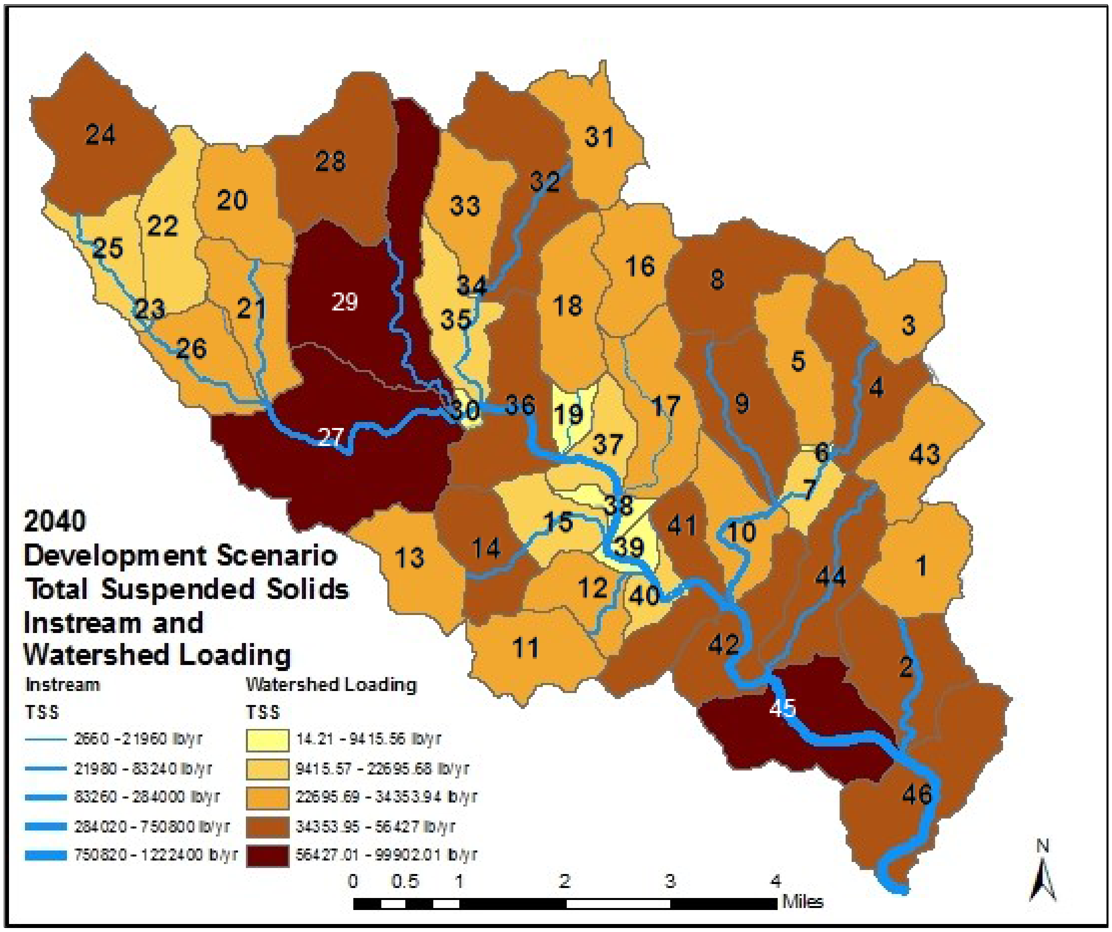


Figure 21. 2040 Future Total Suspended Solids Modeled Instream Loads

Bacterial Loads

E. coli is a form of bacteria that is used as an indicator of bacterial pollution which is often present when contamination exists from to untreated sewage, manure, wildlife or pet waste. Historical and recent monitoring data indicate that at flows below 2 cfs, *E. coli* exceedances occur at the RR12 bridge downtown. The bridge runs through downtown Wimberley and over Cypress Creek near the Square. A bat colony was discovered under the bridge and is a likely contributor of *E. coli* that may be exacerbated during low flow conditions. Another major source of *E. coli* is the high concentration of aging and overloaded OSSFs in the downtown area. Additional monitoring during the first 3 years of WPP implementation will determine whether this is a significant source of bacteria and if management measures are required.

Additional monitoring data indicates that high *E. coli* concentrations also were observed upstream of the bridge, closer to Blue Hole. The presence of residential land uses, coupled with this data suggests that *E. coli* is contributed by septic systems and potentially from pet/animal waste that flows into the creek. Higher *E. coli* values are correlated with elevated TSS levels at all sites except at Jacob's Well, indicating that overland flow is the likely mechanism for transporting bacteria to the creek (Figure 22, Figure 23). Jacob's Well generally has the lowest bacteria concentrations of location sampled, but also has the greatest variability of observed concentrations due to the influence of varying spring flows.

The Stakeholder Committee determined to set target *E. coli* levels below state standards to maintain the creek's contact recreation designated use. The Stakeholder Committee identified BMPs and a monitoring strategy that will comprehensively address this concern.

E. coli was modeled for the existing and future scenarios using EMCs to determine a percent increase and identify subwatersheds that are contributing the largest amounts of bacteria to the creek (Figure 24 and Figure 25). For more detailed information on *E. coli* loading refer to Section 6.3 of the WCR (Technical Resources Document).

Stakeholders identified priority reaches 2, 12, 15, 36, 41, 42, 44, 45, and 46 because they have relatively high bacteria loads. Stakeholders identified the priority subwatersheds to include 1 and 13 because they have baseline overland bacteria contributions above the target.

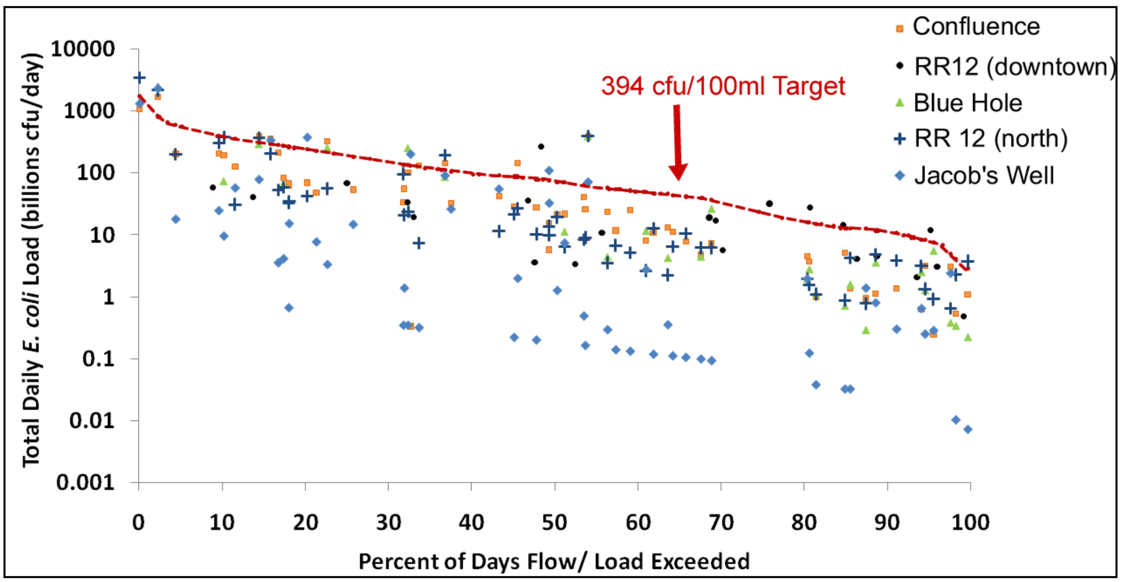


Figure 22. Load Duration Curve of *E. coli* At Five Sites Along Cypress Creek.

The red dashed line represents E. coli loads at a target concentration of 394 cfu/100ml, and dots represent loads calculated for observed conditions.

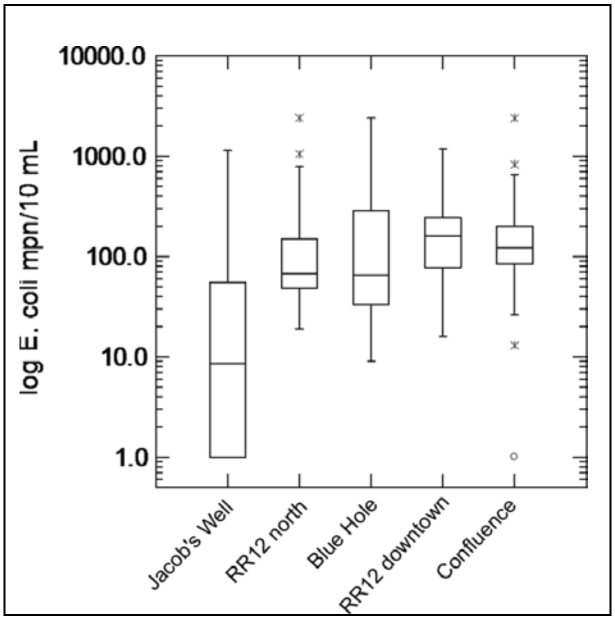


Figure 23. *E. coli* (cfu/100 ml) Measured At Five Sites.

The SELECT model was used to estimate *E. coli* loads from pets and wildlife. Because those numbers are based on real situations, future conditions cannot be estimated using the SELECT approach. EMCs for Fecal Coliform, an indicator for *E. coli*, were used to estimate loading under 2009 land uses and the future development scenario by subwatershed (Figure 11). The EMC calculation results show that total Fecal Coliform loads for the watershed may increase by nearly 300% (Table 18). While the modeling did not indicate *E. coli* annual exceedances in the Future Scenario, the Stakeholder Committee determined adhering to existing state standards for *E. coli* is best to maintain Cypress Creek's contact recreation designated use of Cypress Creek.

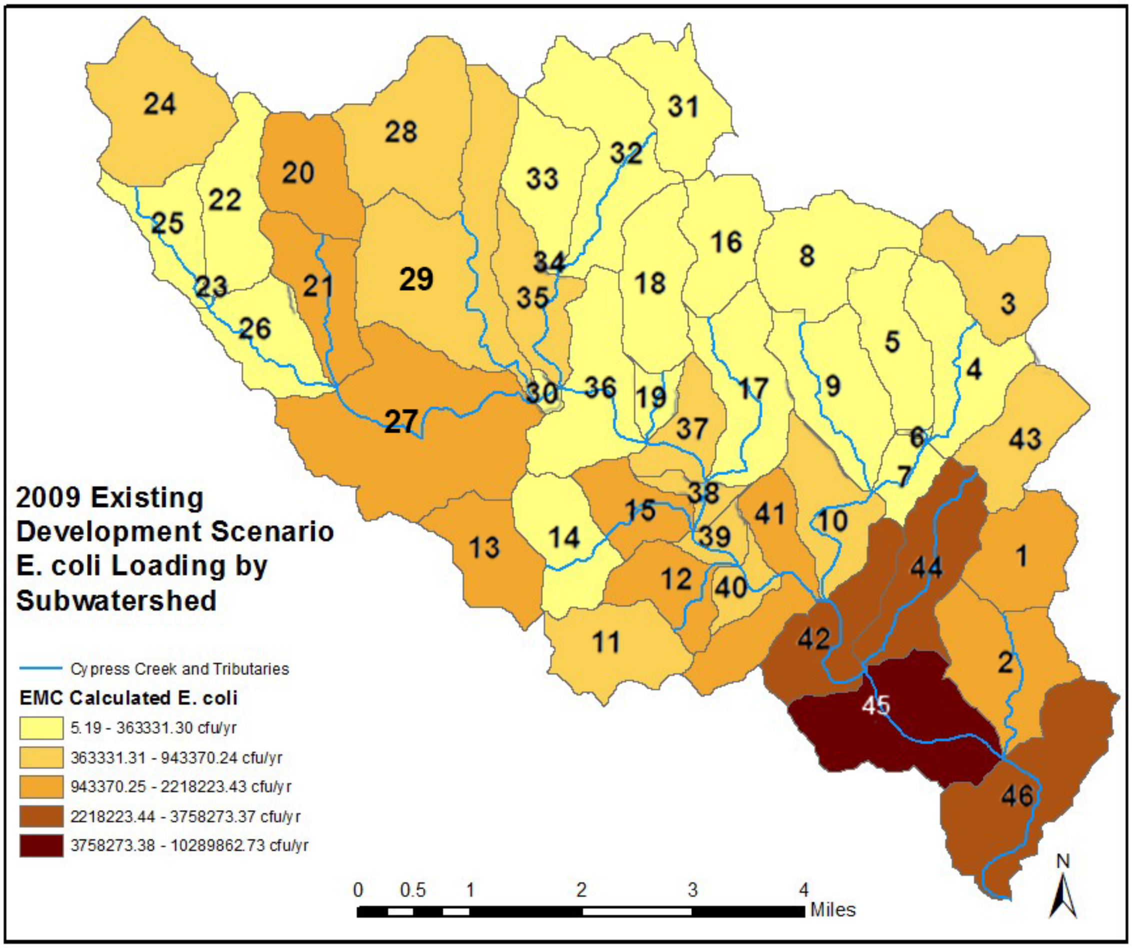


Figure 24. EMC Calculated 2009 *E. coli* Loadings By Subwatershed

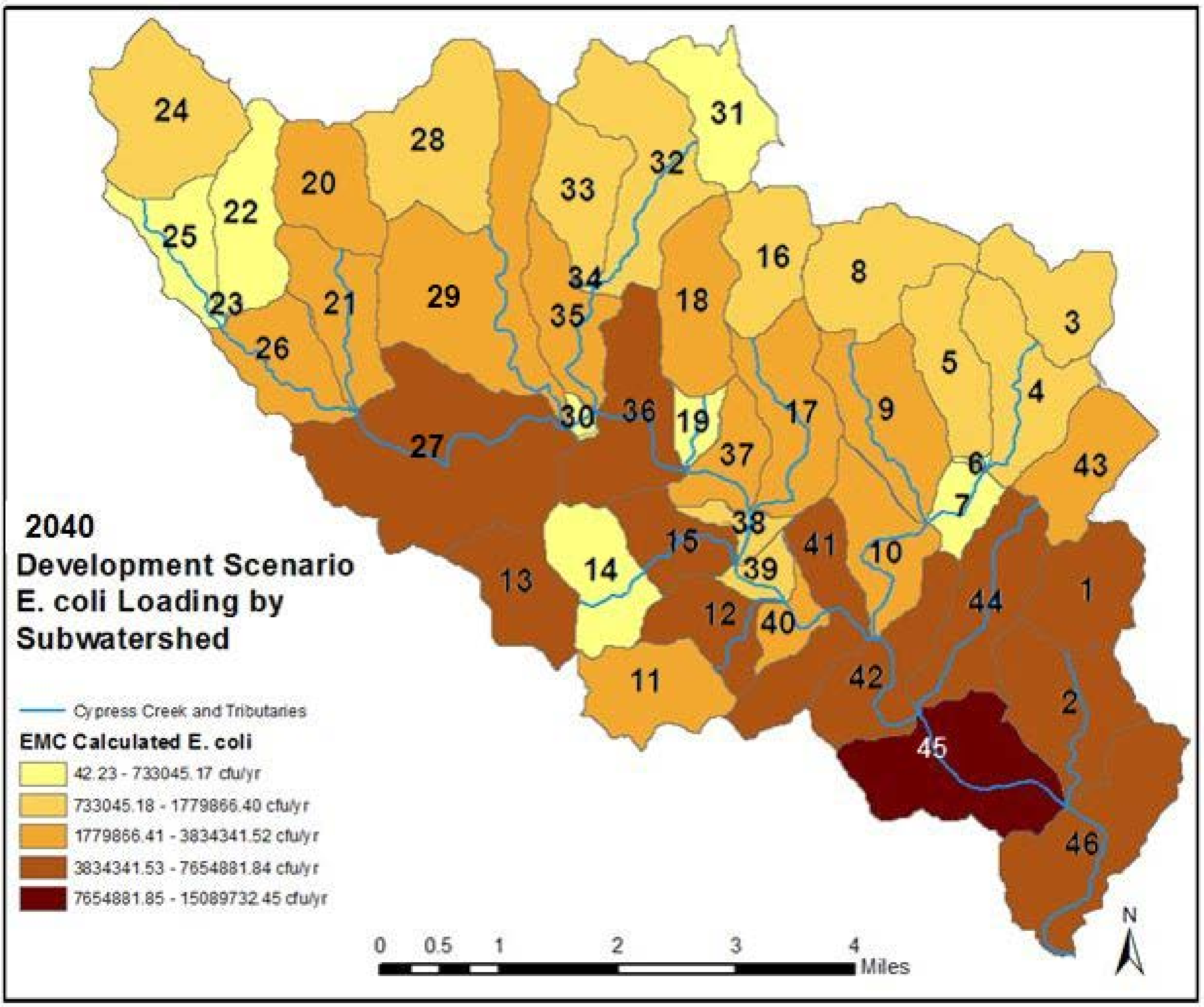


Figure 25. EMC Calculated Future *E. coli* Loadings By Subwatershed

Table 18. Total Current and Future Fecal Coliform Loadings

Total Existing calculated Fecal Coliform loading in cfu/year	Total Future calculated Fecal Coliform loading in cfu/year	Percent loading increase
45,210,755.66	128,104,549.17	283%

Parameters of Concern

The Stakeholder Committee chose to monitor indicators of threats to Cypress Creek's exceptional aquatic life and contact recreation designated uses. EMC calculations were used to identify potential Oil and Grease which is an indicator of failing septic tanks. The Stakeholder Committee also determined that maintaining adequate flows from Jacobs Well are essential to the preserving water quality in Cypress Creek. These parameters of concern can be viewed as indicators of water quality degradation as the Cypress Creek watershed experiences increased urbanization. These parameters (and indicators) are part of the Stakeholder Committee's comprehensive strategy to protect surface water quality and adequate groundwater levels in the aquifer that feeds Cypress Creek.

Oil and Grease

The majority of subwatersheds are estimated to have loading potentials for oil and grease. Subwatersheds with oil and grease loadings of concern in the Future Scenario are located in the southern region of the watershed and a section of the dry portion of the watershed. While no state water quality standards exist for oil and grease, the Stakeholder Committee identified this as a parameter of concern in their watershed. Under the future development scenario, modeling estimates over a 500% increase of oil and grease (Table 19). Primary sources for oil and grease are contributed by residential OSSFs and Commercial land use activities, and to a much lesser extent, Industrial and Transportation areas. The Stakeholder Committee determined that a 300% increase of oil and grease could be an indicator of failing septic systems or other water quality concerns. Additional information can be found in 7.2 Pollution Potential in the Watershed Section of the WCR, found in the Technical Resources Document.

Table 19. Total Current and Future Oil and Grease Loadings

Total existing calculated oil and grease loading in lb/yr	Total future calculated oil and grease loading in lb/yr	Percent loading increase
4587.57	25830.49	563%

Dissolved Oxygen

Cypress Creek was impaired for low Dissolved oxygen (DO) and listed on the 303(d) list in 2000. This impairment coincided with the first time in recorded history that flow at Jacob's Well Spring was reduced to zero cfs. The 5 water quality monitoring sites along the Cypress Creek provided the data used for statistical analyses of flow and DO.

Multivariate linear regression indicated strong correlations between low DO levels ($p < .05$), low flows and suspended solids ($p < .05$). DO levels above 6.0 mg/L are necessary to maintain the creeks exceptional aquatic life designation (Table 10). Though the creek was delisted, the Stakeholder Committee identified adequate DO levels a primary concern and maintaining preferred flows (

Table 20) in Cypress Creek a priority. Monitoring data shows that consistent preferred flows from Jacobs Well equate to higher base flows in Cypress Creek and adequate DO levels.

Stakeholders identified priority reaches 41, 42, 45, and 46 because they make up the main stem of Cypress Creek in the wet portion and can be subject to low DO during times of low flows.

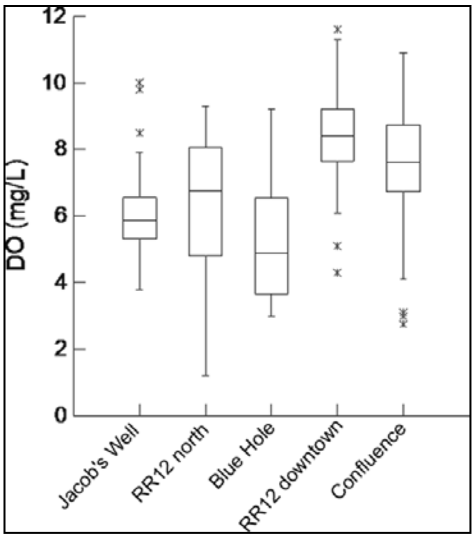


Figure 26. Box-and-Whisker Plot Of Dissolved Oxygen (Mg/L) Measured at Five Sites

Flow levels (given in cubic feet per second) correspond to the 10th, 20th, 30th, etc. percentile of flows estimated at the Cypress Creek confluence, 2000-2009. In this chart, a flow level of 0.9 reflects DO concentrations measured when flow is ≤ 0.9 cfs, 1.3 indicates flow from 0.91 to 1.3 cfs, etc.

Table 20. Comparison of Flows at High And Low Oxygen Levels

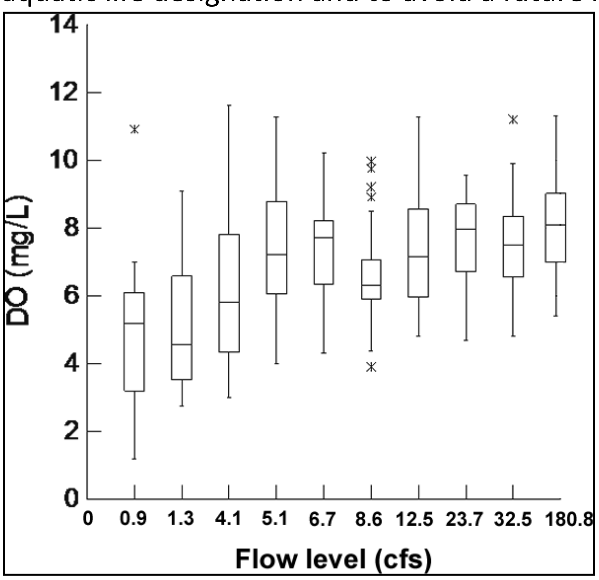
	RR12 north 12676		Blue Hole 12675		RR12 downtown 12674		Confluence 12673		Jacob's Well 12677	
	DO <6.0	DO ≥6.0	DO <6.0	DO ≥6.0	DO <6.0	DO <6.0	DO <6.0	DO ≥6.0	DO <6.0	DO ≥6.0
N of cases	21	36	17	10	24	24	10	50	24	9
Flow Min (cfs)	0.30	0.86	0.30	3.82	0.00	0.00	0.30	0.52	0.00	0.01
Flow Max (cfs)	9.50	180.7 6	28.33	39.45	26.00	26.00	6.71	180.76	26.00	9.90
Flow Mean (cfs)	3.17	23.35	4.28	12.89	5.28	5.28	1.65	19.05	5.28	3.28

Flows estimated at confluence (a) and measured at Jacob's Well (b) calculated for DO measurements above and below the target threshold of 6.0 mg/L. For all stream segments, mean flow is much lower when DO <6.0 mg/L. For Jacob's Well, the opposite is true, indicating that maintaining adequate flow throughout the length of the creek is critical for maintaining its historical condition as a spring-run creek.

Dissolved oxygen (DO) is a very important indicator of a stream's ability to support aquatic life. TCEQ standards for DO in the Cypress Creek require that 24-hour mean values do not go below 6.0 mg/L, and that individual grab samples do not fall below 4.0 mg/L. Factors influencing DO levels include flow, the physical conditions of a given reach, water temperature, sediment and dissolved solids. During higher flows, rushing water is aerated by bubbles as it churns over rocks and down waterfalls, causing DO to be relatively high. As water slows down behind small dams and becomes more stagnant, oxygen only enters the top layer of water, and deeper water is often low in DO concentration due to decomposition of organic matter by oxygen-depleting bacteria that live on or near the bottom. Colder water can hold more dissolved oxygen, so spring-fed streams such as Cypress naturally have very high levels. As flow decreases and channels widen and are exposed to more sun, temperature can increase and cause DO to drop. During rainy seasons, oxygen concentrations tend to be higher because the rain interacts with oxygen in the air as it falls. Higher levels of sediment and dissolved solids can also decrease DO in the stream. Higher nutrient levels can also affect DO by allowing for greater algae or plant growth, which generate oxygen during photosynthesis. This can cause the stream to become super-saturated with oxygen during the day (due to photosynthesis) and drop sharply at night (due to respiration). Algal blooms can also cause eutrophication as they decompose, severely reducing oxygen necessary to support aquatic life.

Although the water which emerges from Jacob's Well is low in Dissolved Oxygen from the aquifer environment, it soon becomes oxygenated (Figure 26) as it interacts with the surface air and photosynthesizing plants. When the well flow and velocity decreases it is detrimental to DO levels, indicating a strong reliance on groundwater supply for healthy DO in the creek (See the Ground/source Water Protection Strategy in the Technical Reference Document).

Further evidence that flow plays a critical role in dissolved oxygen concentrations is seen when examining plots of dissolved oxygen across a range of flow levels. 10th, 20th, 30th, etc. percentiles were calculated for flows estimated at the confluence from 2000 to 2009 and DO observations plotted at each level (Figure 27). For all sites, a flow level between 1.31 and 4.1 cfs appears to be sufficient to sustain DO levels above 4.0 mg/L at least 75% of the time. Between 4.11 and 5.1 cfs, DO is above 6.0 mg/L at least 75% of the time, which is the target level. Stakeholder consensus is that it is imperative that flows at Jacob's Well Spring be preserved at or above a minimum level of 4.1 cfs to maintain Cypress Creek's exceptional aquatic life designation and to avoid a future impairment.



Flow levels (given in cubic feet per second) correspond to the 10th, 20th, 30th, etc. percentile of flows estimated at the Cypress Creek confluence, 2000-2009. In this chart, a flow level of 0.9 reflects DO concentrations measured when flow is ≤ 0.9 cfs, 1.3 indicates flow from 0.91 to 1.3 cfs, etc.

Figure 27. Dissolved Oxygen (Mg/L) By Flow Level.